



Office of the Chief Investigator  
Transport Safety

**Rail Safety Investigation  
Report No 2011 / 05**

**Derailment  
Tram 3515  
Melbourne University Terminus  
20 April 2011**





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## **THE CHIEF INVESTIGATOR**

The Chief Investigator, Transport Safety is a statutory position under Part 7 of the *Transport Integration Act 2010*. The objective of the position is to seek to improve transport safety by providing for the independent no-blame investigation of transport safety matters consistent with the vision statement and the transport system objectives.

The primary focus of an investigation is to determine what factors caused the incident, rather than apportion blame for the incident, and to identify issues that may require review, monitoring or further consideration. In conducting investigations, the Chief Investigator will apply the principles of 'just culture' and use a methodology based on systemic investigation models.

The Chief Investigator is required to report the results of an investigation to the Minister for Public Transport or the Minister for Ports. However, before submitting the results of an investigation to the Minister, the Chief Investigator must consult in accordance with section 85A of the *Transport (Compliance and Miscellaneous) Act 1983*.

The Chief Investigator is not subject to the direction or control of the Minister in performing or exercising his or her functions or powers, but the Minister may direct the Chief Investigator to investigate a transport safety matter.



## EXECUTIVE SUMMARY

At about 0743 on 20 April 2011, Combino Tram 3515 operated by Yarra Trams arrived at Melbourne University terminus from the city. The tram was to terminate at this stop and then shunt, changing direction for the return journey. However, at the time of its arrival, all three shunts<sup>1</sup> at the terminus were occupied.

To clear the tram stop platform, the duty traffic officer overrode the automatic control systems and manually moved the points to allow Tram 3515 to enter the first shunt and abut a tram that was already stabled there. As the tram moved into the shunt the points moved under it. The front bogie travelled into the shunt and the rear bogie travelled along the straight. This resulted in both tram bogies derailing. There was no reported injury to persons or damage to the tram or infrastructure.

The investigation found that the tram derailed when the automatic Points Controller moved the points, seeking to place the tram in the second shunt. The automatic Points Controller had functioned as designed and the points would have been locked in position and not have moved, had the tram been detected moving towards the points, which it was not.

The investigation determined that the failure of the system to initially detect Tram 3515 was due to defects in a number of the tram's earth brush units that are mounted within the wheel assembly and facilitate an electrical connection between the rails. These units have a history of malfunctioning in the Combino tram.

The investigation found that the Melbourne University terminus control systems had been designed to stable only one tram in each shunt position but the operator had changed their operational practice to allow two trams to be stabled in the first shunt without conducting an adequate risk assessment and without considering infrastructure design.

Since the incident Yarra Trams have initiated operational and engineering procedures to mitigate the risk of a similar incident occurring.

The investigation makes a recommendation to Yarra Trams that it review internal processes for changing operational practices.

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<sup>1</sup> Track configured to switch trams from one track to another, and at Melbourne University terminus to stable trams until they are required to operate another service.





## **1. CIRCUMSTANCES**

### **1.1 The incident**

On 20 April 2011, Tram 3515 operated by Yarra Trams was conducting a scheduled service on Route 6 from Glen Iris to Melbourne University terminus. At 0743, the tram arrived at the Melbourne University tram stop and was required to shunt to facilitate the return journey.

As the tram approached the terminus the driver transmitted a command to the automatic Points Controller<sup>2</sup> indicating that the tram was required to shunt. As all three shunts were occupied, the command was stored in the controller.

A short time later, another tram arrived behind Tram 3515. The traffic officer noted that there was sufficient space in № 1 Shunt to accommodate a second tram, so he manually switched № 1 points to enable Tram 3515 to enter № 1 Shunt. At about the same time the tram that was in № 2 Shunt departed to conduct its next service, thus freeing the shunt for another tram.

At 0746, Tram 3515 commenced moving along the main line towards № 1 Shunt. At about the same time as its leading bogie was at № 1 points, the Points Controller recognised that № 2 Shunt was vacant and acted upon the stored command from Tram 3515 and attempted to route it into № 2 Shunt. This involved re-setting the № 1 points back to the straight (main line). However, the points were held in position (for entry into № 1 Shunt) by the tram's leading bogie, but as soon as the bogie cleared the points they switched back to the main line.

This resulted in the leading bogie of Tram 3515 travelling into the shunt and the rear bogie travelling along the straight. As a consequence both bogies derailed. There was no damage to the tram or the infrastructure and no reported injuries to persons.

There was light drizzle at the time of the incident.

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<sup>2</sup> The electronic system that controls the setting of the track points to facilitate tram movements into the sidings.



## **2. FACTUAL INFORMATION**

### **2.1 Melbourne University tram terminus**

#### **2.1.1 Tram stop**

Melbourne University tram stop is located on Swanston Street, Carlton, adjacent to the University of Melbourne campus. Seven tram routes terminate at Melbourne University and another two tram routes operate through the stop. It is the fourth highest patronage tram stop on the Melbourne tram network, and has been identified by the operator as the stop with the highest number of delayed tram movements.

The platform is orientated approximately north-south and is 59 metres long and 6.5 metres wide. At the Down end<sup>3</sup> of the platform is the platform building and traffic officer kiosk.

The new stop was constructed in 2004 and commissioned with a micro-processor based automatic Points Controller.

In accordance with Yarra Trams' maintenance program, the location undergoes weekly track inspection and fortnightly points cleaning.

#### **2.1.2 Shunts**

Trams arriving from the city on the Down track and terminating at Melbourne University use one of the three shunts situated on the Down side of the platform to change to the Up track and return to the city (see Figure 1). No 1 Shunt is 34 metres in length and No 2 and No 3 Shunts are 30 metres in length.

The automatic points control system is designed to accommodate only one tram in each shunt. However, Yarra Trams advised that at times No 1 Shunt was used to stable a block tram<sup>4</sup> and that the traffic officer could use his/her discretion to stable a second tram into that shunt, by manually operating the points. At the time of the incident there was a Z3 Class (block) tram stabled at the end of No 1 Shunt.

#### **2.1.3 In-track equipment**

Figure 2 provides an overview of the in-track equipment at the platform and leading into No 1 Shunt. The track circuitry leads to the automatic Points Controller which is located between No 1 & No 2 Shunts.

The One Stud marker is 14.3 metres from the Down end of the platform and the start of Track Circuit 1 is 12.8 metres from the point blades. In 2005, Track Circuit 1 was shortened (at its city end) by 4.2 metres, so as to be able to accommodate two trams at the platform without them sitting over the track circuitry at the same time. The One, Two and Three Stud markers and the AWA (described below) were also moved by the same distance to retain the original distances between them.

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<sup>3</sup> The end furthest from Melbourne CBD.

<sup>4</sup> A tram on standby for use in case the system requires a replacement or an additional tram.

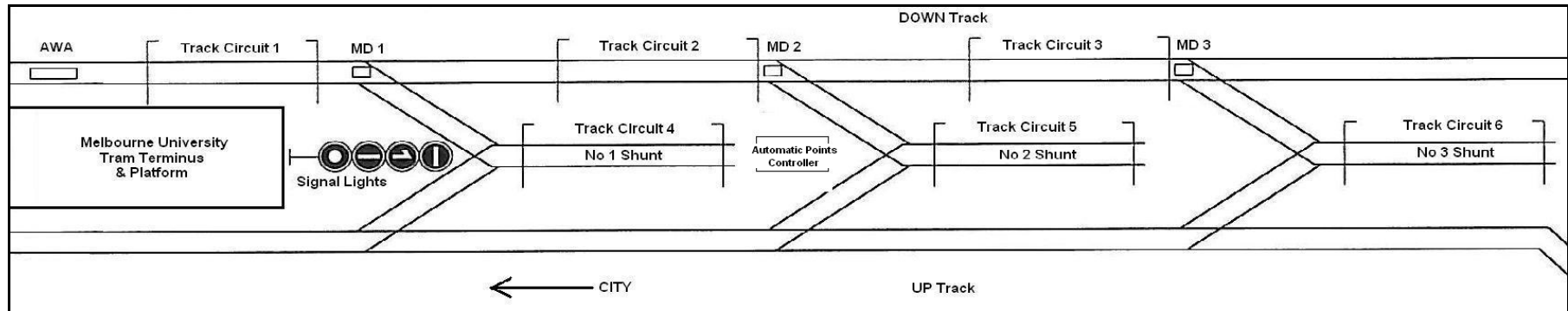


Figure 1 – Diagram of Melbourne University shunts with track components (not to scale)

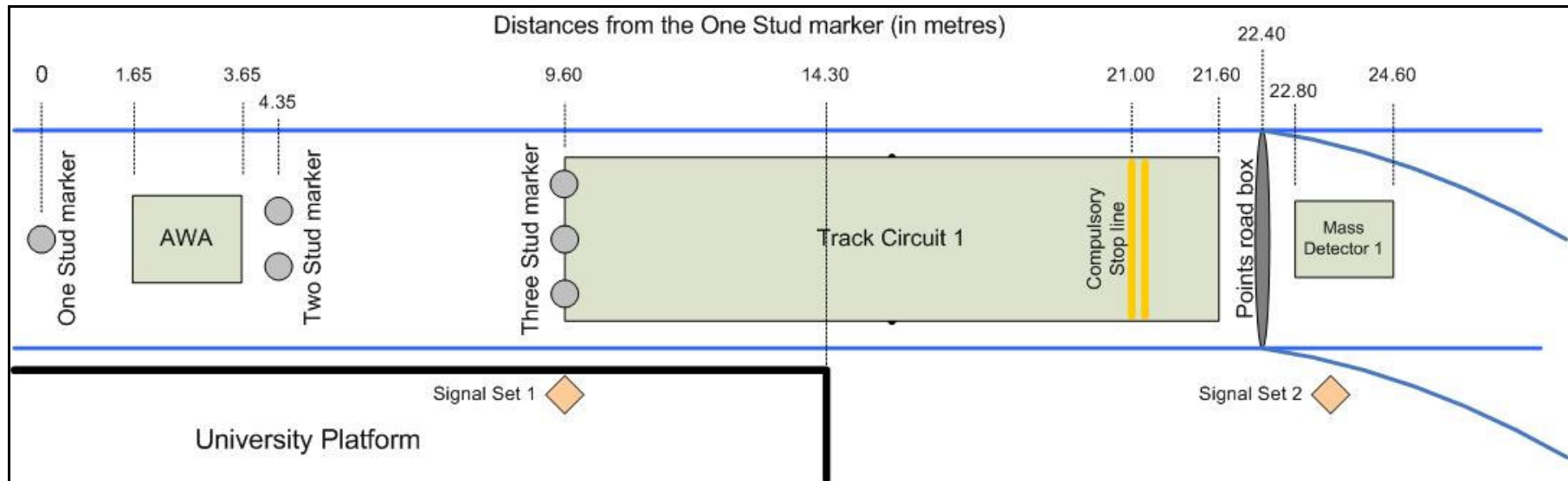


Figure 2 – Track components at Melbourne University platform leading into No 1 Shunt (not to scale)

The operation of components is described below:

**AWA:** The AWA loop (also known as the points transponder loop) relays the tram's points selector command from the tram transponder tag via a receiver unit to the Points Controller.

**Track Circuits:** Track Circuits 1, 2 and 3 are located on the main line prior to the Automatic Points into № 1, 2 and 3 Shunts respectively and Track Circuits 4, 5 and 6 are located in each Shunt respectively. The Track Circuit is an extra low voltage electrical loop (measuring frequency and voltage status) that detects the presence of a tram by a short circuit load (less than 0.3 ohms) between the tram rails, via the tram wheels and earth brush unit. When the presence of a tram is detected by the Track Circuit prior to the automatic points (on the main line) this in turn locks or electrically 'disables' the movement of the point blades and at the same time 'enables' a Mass Detector located immediately after the automatic points, which continues to lock or electrically 'disable' the movement of the point blades.

**Mass Detector:** A Mass Detector (MD1, MD2 and MD3 respectively) is installed immediately after the automatic points. The Mass Detector is an independent extra low voltage loop which detects the presence of metal (measuring frequency and voltage status) immediately above it; in this case a tram passing over it. Only after the tram body has cleared the area of the Mass Detector will the automatic Points Controller unlock or electrically 'enable' the movement of the point blades, should this be a requirement for the next tram.

**Signal Set 1:** Signal Set 1 is a single light mounted on the west side of the Down platform in line with the provisional stopping point (Three Stud marker). In normal operation the signal remains off, illuminating only when the tram is required to stop at the provisional stopping point (steady horizontal white bar), or acknowledging to the tram driver that a stored command has been entered (flashing horizontal white bar). The tram should remain stopped at the provisional stopping point until the signal has switched off.

**Signal Set 2:** Signal Set 2 is a set of four signal lights vertically mounted on a tram overhead pole, beyond the automatic points leading into № 1 Shunt. It hosts (from top to bottom): the shunts are all occupied or full signal (single white dot); all automatic points set to straight (vertical white bar); shunt road (№ 1, 2 or 3) to proceed to or the letter 'F' illuminated as a stored command acknowledgement for the next available Shunt; and the bottom signal indicating a fault within the system (single amber dot). Drivers normally proceed in accordance with the signal light indicator, except when instructed otherwise by an authorised officer, or as instructed by Fleet Operations if the site is out of normal service.

**Compulsory Stop line:** The compulsory stop is marked by two yellow lines installed at 90 degrees between the tram rails prior to the Automatic or facing points. Every tram must stop at this point (Rule 104 – *General and Operational Rules and Procedures*) and may proceed only once the driver has confirmed the lay of the points, appropriate for the required direction of travel for the tram.

**Points road box:** The points road box is a steel enclosure housing the mechanical linkages, which can be changed either manually or automatically to suit the required direction of travel for the tram.

### **2.1.4 Post-incident inspections**

Immediately after the incident № 1 points were found to be set for the main line (straight direction) and Signal Set 2 indicated that the system was set for № 2 Shunt.

Post-incident checks of the infrastructure found that the condition of the rail was satisfactory and the operation of the points and the condition of the point blades was also found to be satisfactory.

The various components of the automatic points controller system including transponders, Track Circuits, Mass Detectors and signals was checked by the operator and found to be operating normally.

## **2.2 Shunt operations**

### **2.2.1 Operational procedures**

Yarra Trams provided the investigation with a draft copy (2010) of its Process Control Document № o601wi0076, *Operation of the Melbourne University Terminus*. The document provides instructions to staff on the operation of trams at Melbourne University terminus, to ensure safety and minimise delays.

The document stated that when the terminus is supervised, drivers must comply with the instructions of any authorised personnel<sup>5</sup> on duty and in case of an auto-points failure, the points can be operated manually.

Three notations in the document stated that:

- Only one tram of any type is allowed to enter any shunt at any time and drivers must proceed to the bottom of the shunt, except under the instruction of authorised personnel.
- If all shunts are occupied, the points will be set for the straight and change to a vacant shunt as per the stored command once a shunt is available.
- Trams can proceed to Elgin Street shunt if delays are experienced in the Melbourne University shunt roads.

A previous memo (May 2009) from the Manager Tram Operations to all traffic officers and depot managers clarified that when shunting trams at Melbourne University, only one tram should be in the shunt at any one time. The only exception allowed was when shunting is supervised by the traffic officer. The memo also advised traffic officers that supervision must only be done from a position at the shunt where the direction of the points can be confirmed, and not from the platform.

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<sup>5</sup> In this case the traffic officer on duty at the platform.

## 2.2.2 Automatic points operation

**NOTE: There is no interface between the VicRoads traffic signalling system and the tram signalling system. Drivers must obey the traffic signals which override any tram shunt signal to proceed.**

The normal operation of the points and signals (Down track) at the Melbourne University Terminus is determined by an automatic Points Controller. The system is designed to permit only one tram at a time to occupy a shunt. When a tram arrives at the terminus from the southern approach (city) and requires to shunt in order to proceed back towards the city, the following sequence of events takes place:

- When a tram arrives at the One Stud marker, the driver wishing to shunt operates a spring loaded selector switch on the driver's console to the right position and holds the switch in that position until the signals change or until the tram arrives at the Two Stud marker. The AWA receives this command from the tram transponder tag, via the AWA loop and transmits it electronically to the Points Controller.
- On signal acknowledgement, the tram proceeds past the Two Stud marker to the provisional stopping point (Three Stud marker) when indicated to do so by Signal Set 1 and proceeds to the displayed shunt when indicated by Signal Set 2.
- If all Shunts are occupied or full, the Points Controller stores a requested command to shunt (only one command can be stored) and operates Signal Sets 1 and 2 to reflect this. The next incoming tram usually waits prior to the One Stud marker until the system indicates that the Points Controller is ready to receive the next command (via the two Signal Sets).
- The Points Controller is programmed to check for vacant shunts and allocates the shunts in a priority order, that being № 1 Shunt has a priority over № 2 and 3 Shunts. When the Points Controller detects that the main line system is clear and a shunt is available, the automatic points are changed for the available shunt to facilitate tram movement into the shunts.
- Once the points are set for the movement, a signal is sent back to the Points Controller, which then changes the light sequence on Signal Set 2 to indicate a proceed signal and the number of the allocated shunt to the driver.
- The tram then proceeds to the shunt and the Points Controller is ready to act on the next command.
- When a tram is detected as occupying Track Circuits 1, 2, or 3, only then does the respective Mass Detector become 'enabled', expecting to see a tram over the points and the system will not reset until the whole of the tram has passed the Mass Detector and exited the point blade area. The reset time after the tram has passed may take up to 3 seconds.
- The relevant shunt Track Circuit (4, 5 or 6 respectively) detects the presence of the tram and sends a signal to the Points Controller not to allocate the occupied shunt. When the tram departs the shunt and enters the main line Up track, the track circuit becomes 'free' to allow the Points Controller to allocate the vacant shunt as required.
- If all three Mass Detectors have indicated a clear track, the Points Controller will start processing the next tram command received and as soon as it detects a vacant shunt, the above sequence is repeated.

Drivers of trams on routes that do not terminate at Melbourne University, or wish to undertake shunting operations further down the main line (if all shunts are full), are not required to enter a direction request via the points selector switch as there is a permanent 'straight' signal transmitted through the AWA loop for straight ahead tram movement (the main line). The Points Controller will set all the automatic points for the straight direction and depict this on the Signal Set 2.

The automatic points system does not operate a 'return to the straight position' following a tram movement through the points. The points, once configured for a particular tram movement, will remain in that configuration until a new point selection is received by the Points Controller.

### **2.2.3 Electronic override of automatic Points Controller**

The Points Controller has a key switch and push button control station located on the western side of the platform building below Signal Set 1. This control station was intended to only be operated by an authorised officer should a driver have a faulty transponder, or who had not placed a shunting command into the system or wished to remove the shunt command and set the main line for straight through travel.

The operation of this control station cannot select a particular shunt, the Points Controller issuing the next available.

### **2.2.4 Manual override of automatic Points Controller**

The designed points and signalling system may be overridden by manually switching (with a point bar tool) any of the automatic points on the main line into a shunt, or if the system is out of normal service. This action can be undertaken irrespective of whether a tram is occupying other sections of the main line (Down track) or shunts.

Normally, when a Track Circuit recognises that a tram has occupied it, the corresponding Mass Detector will be 'enabled' and ready to monitor the tram move over it. Once the moving tram has cleared the Mass Detector the system will revert for the next automated operation. However, if the Track Circuit does not detect the tram, the Mass Detector will not 'enable' resulting in the tram being unprotected from any electrical point blade movement; that is, the tram would be 'blind' in the system.

## **2.3 Points Controller data logger**

The recorded data from the automatic Points Controller data logger indicates that when Tram 3515 arrived at Melbourne University, the driver entered a right command for a shunt allocation. At this time the shunt full light was on, indicating all shunts were occupied. Two minutes later, № 1 automatic points were manually changed from the straight to the curve or shunt position. Some time later the tram commenced its move into № 1 Shunt, although the system did not record the start of this movement, as the tram was not yet detected on the Track Circuit. At this point the movement would have proceeded without incident.

The departure of the tram from № 2 Shunt initiated a further set of events. About seven seconds after the points were manually changed, № 2 Shunt was detected as being clear (after the tram that occupied it had departed) and slightly less than one second later, Tram 3515 was allocated № 2 Shunt by the automatic Points Controller.



The № 1 points received a left command (to return to the straight) and № 2 points receive a right command for the tram to access № 2 Shunt. About one tenth of a second later and after the automated command on the points, Tram 3515 was detected on the Track Circuit 1, but the points had already been activated to move. № 1 points were detected as in position for the straight (main line) about 1.6 seconds after the automated command on the points and about eight tenths of a second after № 2 points were detected as being set to the right.

The delay in № 1 points being detected as set for the straight was probably due to the point blade being held up by the wheels of the leading bogie of Tram 3515 as it took the right turn towards № 1 Shunt.

## **2.4 Personnel**

### **2.4.1 Driver**

The driver of Tram 3515 commenced employment as a tram driver (with the Victorian Public Transport Corporation<sup>6</sup>) in July 1986. At the time of the incident he was stationed at the Malvern depot and was approved to drive D and Z Class trams. His last medical examination was conducted in January 2011 at which time he was found to be fit for duty. His last driver check trip was conducted a few days prior to the incident, at which time he was assessed as competent.

On 20 April the driver reported for duty at 0638 and was assigned Tram 3515. At about 0658 he departed the Glen Iris terminus on Route № 6 and arrived at the Melbourne University terminus at about 0743. The driver stated that when the tram arrived at Melbourne University, he stopped his tram at the Three Stud marker and waited for a shunt signal.

He stated that the traffic officer changed the points manually for № 1 Shunt and advised him that Tram 3515 could now enter the shunt, so he proceeded slowly. The tram had just entered the shunt when he felt it jump and the rear bogie derailed and the front bogie was pushed off the rails. When he alighted from the tram, the driver found that the № 1 points had switched back to the straight.

### **2.4.2 Traffic officer**

The traffic officer<sup>7</sup> at Melbourne University commenced employment as a tram driver (with the Victorian Public Transport Corporation) in September 1991. In April 2004 he obtained his Traffic Officer Driver accreditation. At the time of the incident he was stationed at the Glenhuntly depot and was qualified to drive A, B, C, W and Z Class trams and to act as an authorised traffic officer. His last traffic officer refresher training was conducted in May 2010. A few days after the incident the traffic officer successfully completed his next scheduled medical examination.

On 20 April the traffic officer reported for duty at 0600 and was assigned to the Melbourne University platform. He stated that when Tram 3515 arrived at the terminus all three shunt sidings at the terminus were occupied. As there were a few trams awaiting entry to the platform, he changed the points manually to allow Tram 3515 to enter № 1 Shunt, to clear the main line for the through trams.

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<sup>6</sup> The operator of the Melbourne tram network at that time.

<sup>7</sup> Formally designated "Traffic Officer Driver"; persons occupying this position are also required to be a qualified driver.

The traffic officer stated that after allowing for the tram to enter the shunt, he moved aside and noticed that № 2 Shunt was being vacated. He then turned around to indicate to the driver of the next tram in line to move forward. The driver of that tram gestured to him to turn around and when he did he saw that Tram 3515 had derailed. The traffic officer said that while the front of the tram had entered the shunt correctly, the rear had “for some unknown reason” proceeded along the straight track.

## 2.5 The tram

### 2.5.1 Specifications

Tram 3515 is a D class Combino three-module tram built by Siemens and has been operating on the Melbourne metropolitan tram network since June 2003. The tram has a length of 20.04 metres, width of 2.65 metres and weighs 25.8 tonnes. The distance between the axles of each bogie is 1800 mm and the distance between the inner axles of the two bogies is 9640 mm, as indicated in Figure 3.

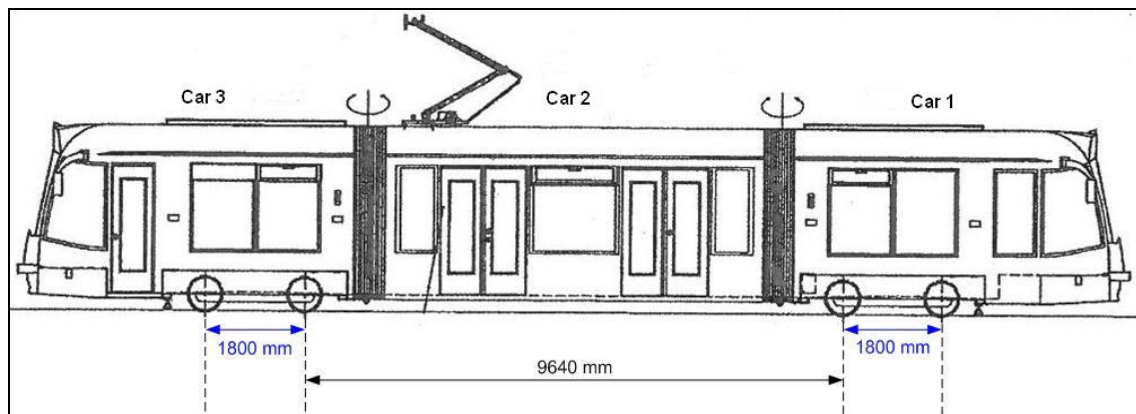


Figure 3 – D class Combino three-module tram

### 2.5.2 Maintenance history

At the time of the incident, the tram was up-to-date in its maintenance schedule having completed its 60-week service on 10 February 2011 and a 5-week service on 10 March 2010 and on 19 April 2010, the day before the incident.

The 60-week service also included the 15-week inspection and superficial cleaning of the earth brush units (see Section 2.6). At this inspection, the earth brush lengths were measured and found to be within specifications<sup>8</sup>. However, wheel resistance measurements were not carried out as they were not a requirement of this inspection.

### 2.5.3 Post-incident inspection

Following the incident, Tram 3515 was driven to the Malvern depot for inspection by Yarra Trams' engineering department. When the wheel earth system was checked, it was found that there were open circuits in the earth brush units on wheels 2, 4 and 12.

There were no other identified tram defects relevant to the incident.

<sup>8</sup> The length of an earth brush should be between 2mm and 10mm.

## 2.6 Earth brush unit (EBU)

### 2.6.1 EBU function and current paths

The EBU serves two purposes: to complete an electrical connection through the tram from rail-to-rail and so allow the tram to be recognised by the Track Circuit; and to provide electrical connection between the tram's traction system and the rails. All wheels on each motor bogie are fitted with an EBU.

For a tram to be detected by a Track Circuit, there needs to be an electrical connection across the rails, via the tram wheels and their interconnection. The Combino tram does not have wheel-to-wheel axles, and in their absence the EBUs provide an electrical path between the rotating wheels and fixed tram components, which are in turn electrically connected across the tram.

For each motor bogie there are electrical connections between both the directly and the diagonally opposing wheels, providing a level of redundancy. Therefore, for a bogie to be detected on a Track Circuit, at least one EBU on each side of the bogie must be serviceable. Yarra Trams' procedures required only one circuit (lateral or diagonal) in the tram to provide a closed loop for the tram to remain in service.

Figure 6 shows the wheel configuration of the D class Combino and the lateral and diagonal electrical interconnection between wheels. The EBUs found to be defective on Tram 3515 are highlighted in red.

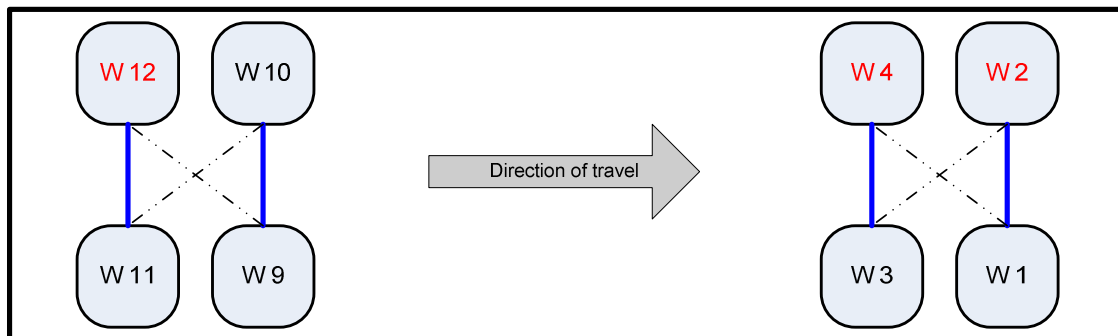


Figure 4 – Wheel configuration of D class Combino tram and defective EBU on tram 3515 (in red)

## 2.6.2 EBU Version 3 description

The EBU comprises a copper earth brush that screws into the earth brush cover to make contact with the copper contact washer. The contact washer is spring loaded so that it maintains continuous contact with the earth brush.

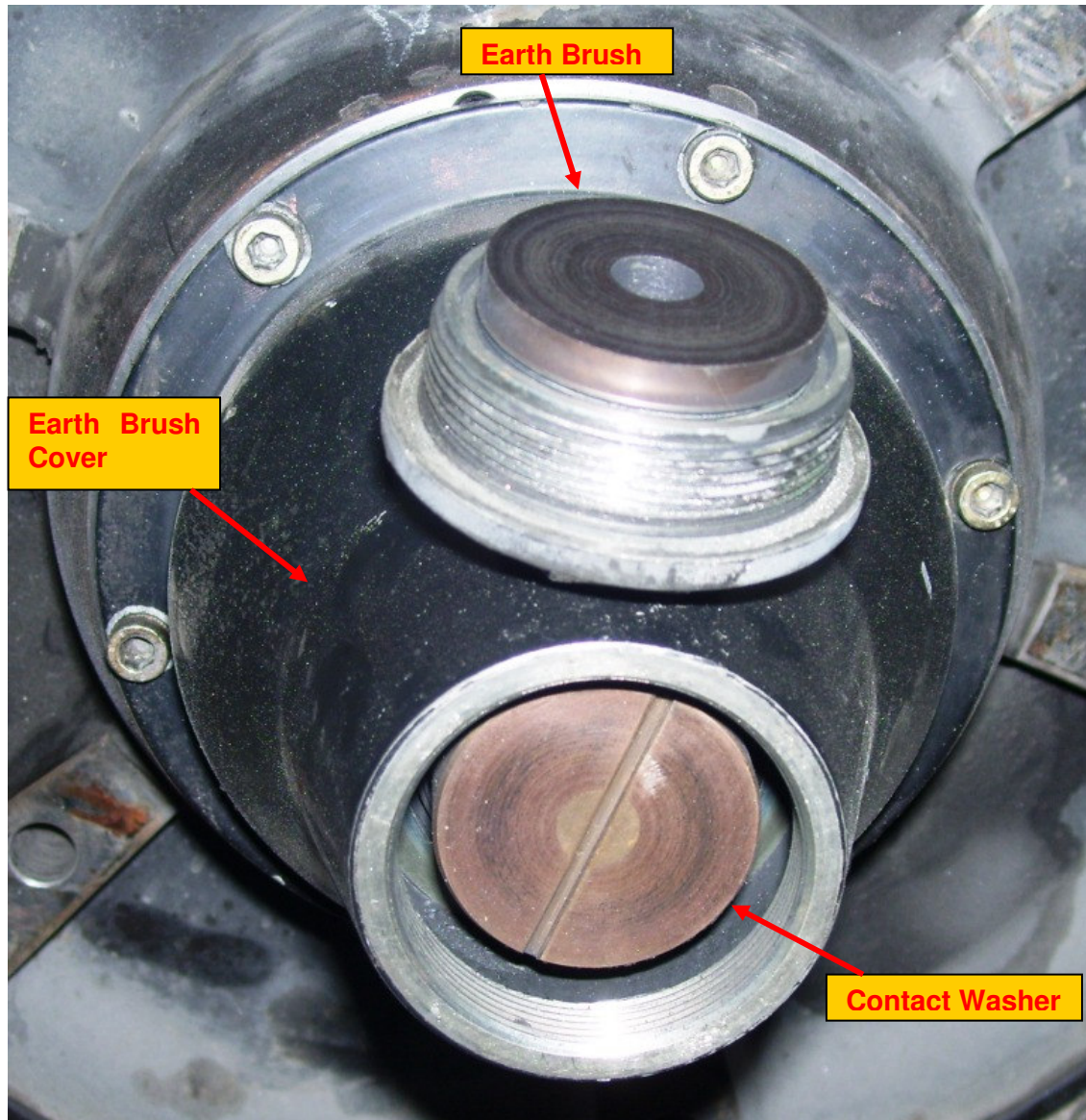
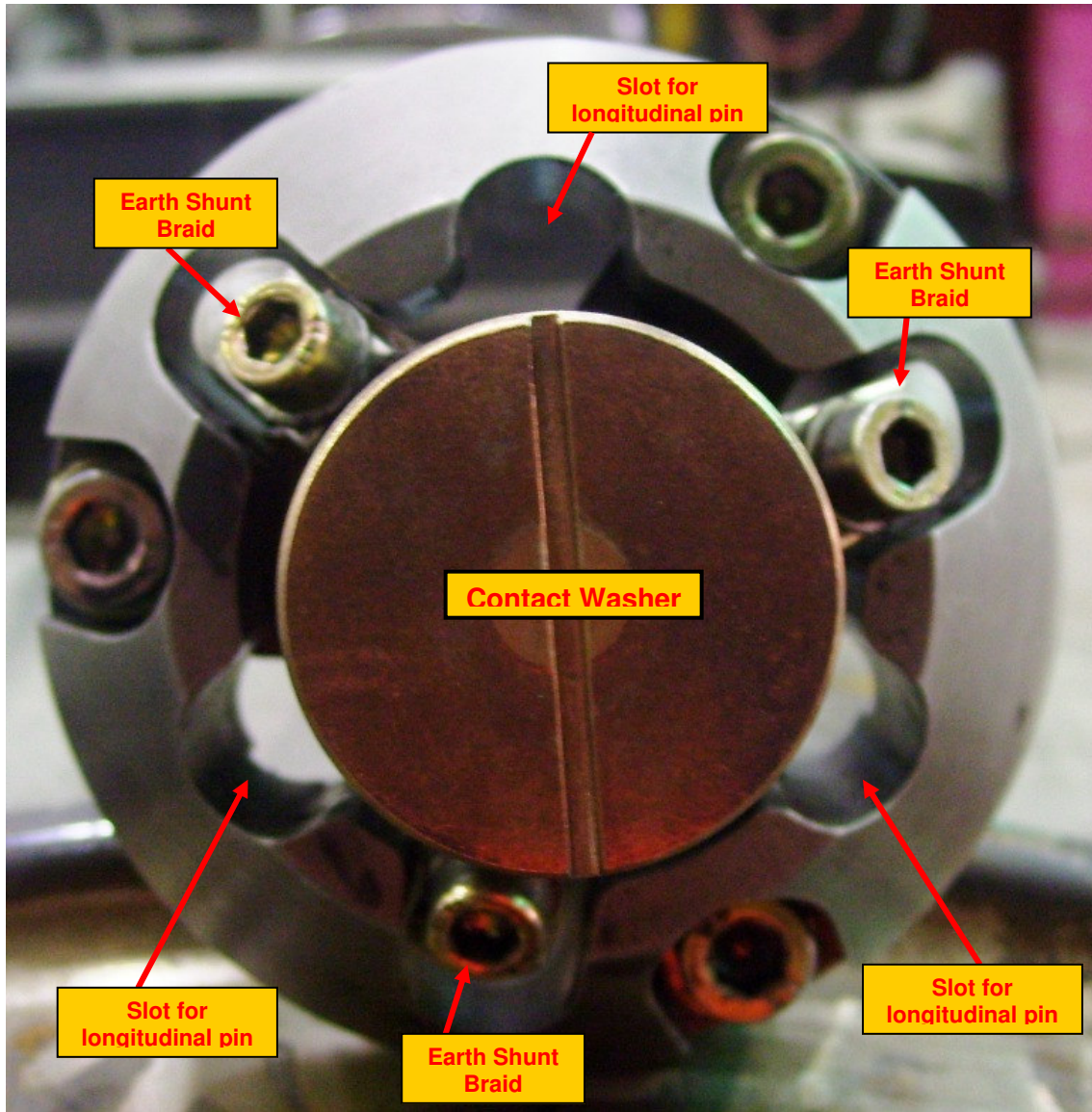


Figure 5 – Earth brush unit, external view

Connectivity between the contact washer and the tram wheel is through three earth shunt braids. As long as one earth shunt braid is intact and the earth brush makes contact with the contact washer, the circuit is closed and resistance measurement that is within limits is obtainable. However, the condition of the parts cannot be determined unless the unit is stripped and inspected.

Version 3 of the EBU was fitted to Tram 3515 and at the time of the incident was the latest model of the EBU produced by this manufacturer. This version did not include longitudinal pins to restrict rotation of the contact washer, although the slots for the pins are still evident in the surrounding casing (see also section 2.6.4)



**Figure 6 – Contact washer and earth shunt braids EBU Version 3**

Track circuit recognition is effective for earth brush resistance measurements up to 300 milliohms; however, optimum recognition occurs when the resistance measurement of each unit is less than 50 milliohms.

### **2.6.3 Inspection, testing and maintenance**

When the Combino trams first entered service, in accordance with the manufacturer's instructions, EBUs were inspected during the tram's 60-week service. The inspection regime frequency was increased to every 15 weeks in November 2007, when the operator noted that the EBUs were wearing out more quickly than indicated in the manufacturer's maintenance manual.

At the 15-week inspection the earth brushes were removed and their length measured. The condition of the earth brush and contact washer was checked, a superficial clean carried out and the earth brush re-connected. At this inspection the earth shunt braids were not checked as they could not be accessed without dismantling the wheel.

If at the 15-week inspection there was a noted deterioration of the EBU, then the bogie was removed from the tram and sent to the workshop for repair. The entire repair took between five and seven days to complete, during which time the affected tram remained out of service.

The operator has also indicated that prior to the incident they were more concerned with the wear on the brush faces and dirt ingress into the wheel bearings and whilst Yarra Trams followed the revised instructions from the manufacturer, they had no reason to believe that the earth shunt braids could snap. Therefore, they did not consider it necessary to inspect the earth shunt braids at the 15-week inspection or undertake wheel resistance tests.

The operator advised that between scheduled inspections they depended on drivers reporting if they noticed that the tram was not being detected by automatic points circuits.

### **2.6.4 EBU history**

Yarra Trams advised that there have been on-going problems with the EBUs installed on Combino trams since they commenced operation in 2003. In the original version, copper dust from the brush wear surfaces found its way into the wheel bearings. The seal was improved in Version 2 (2005) but did not completely eliminate dust ingress to the wheel bearing. Also, a 'chatter' problem was detected where the copper contact washer was found to be making and breaking contact with the rotating earth bush at a high frequency. Yarra Trams advised that the problems in this version also led to wheel bearing failures.

The latest version (May 2008) currently installed<sup>9</sup> has a reduced mass contact washer and stronger spring within its fitting to overcome the chatter. It is also fitted with an improved rubber seal. This modification eliminated the longitudinal pins which were fitted (see Figure 5) to prevent rotational movement of the contact washer that occurred in prior versions. However, this version has not proved to be completely successful.

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<sup>9</sup> The modifications to Tram 3515 wheels were completed in December 2009.

## 2.6.5 Yarra Trams investigation of EBU failures

Following their findings regarding the EBUs in Tram 3515, Yarra Trams commenced wheel resistance measurement testing<sup>10</sup> of the entire fleet of Combino trams. It was found that 12% of the units failed to meet the required resistance with three trams being removed from service due to their failure to meet the minimum criteria for track recognition.

Yarra Trams' investigation also identified that:

- There was excessive earth brush wear.
- The rubber sealing ring was not adequate and permitted the earth brush particles to enter the rear of the earth brush assembly and subsequently the wheel bearing.
- The contact washer on the earth brush was rotating "back and forth" causing the earth shunt braids to snap as well as causing damage to the aluminium housing.

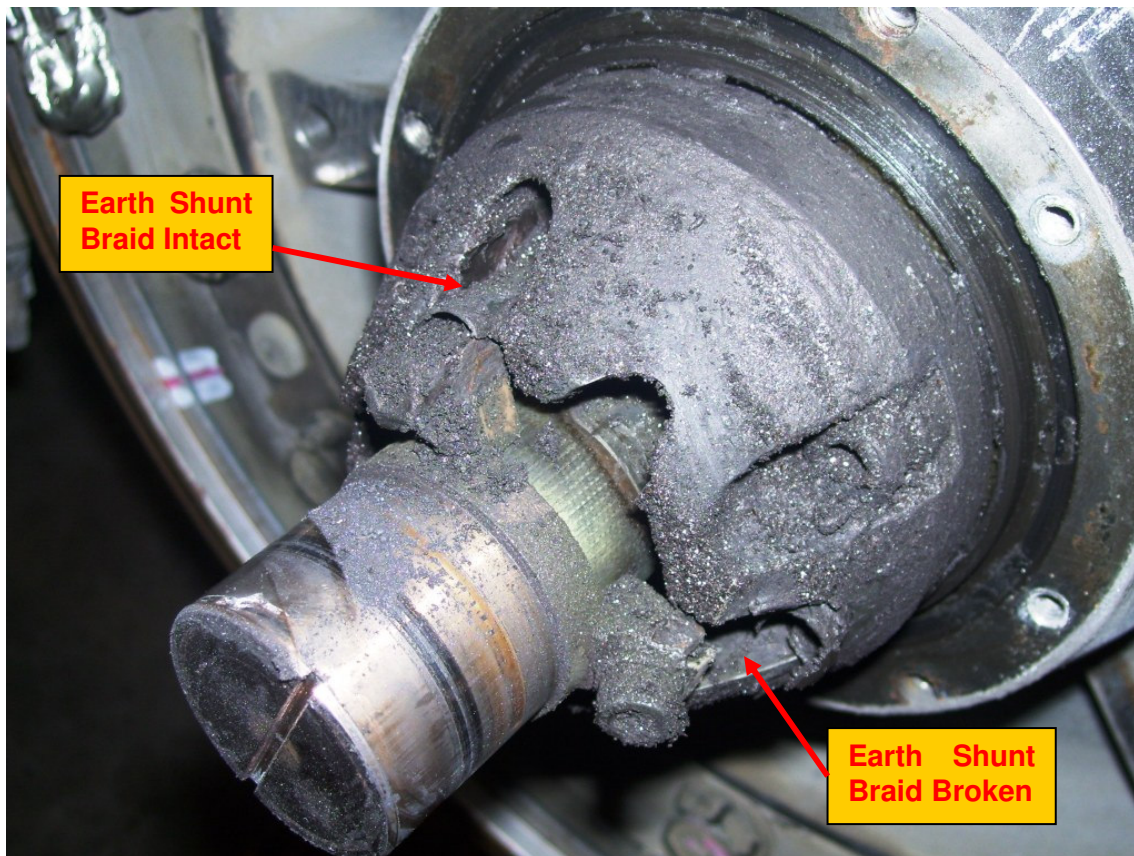


Figure 7 – Typical condition of an EBU after a few weeks in use, as reported by Yarra Trams

Yarra Trams noted that:

- EBUs were not remaining serviceable for planned maintenance cycles and required premature repairs.
- The life-span of an earth brush was between six and 18 months whereas the manufacturer's maintenance manual suggested that the earth brush should have a life-span of eight years.

<sup>10</sup> To verify the functionality of the tram running gear to convey an electrical current in order to shunt a track circuit.

- The repeated replacement of EBUs had also compromised the life expectancy of other key components, such as wheel hubs.

Yarra Trams' investigation report also acknowledged that the correct installation of earth shunt braids with regard to their correct orientation needed to be verified with the tram manufacturer (see Section 2.6.6).

### **2.6.6 Tram manufacturer investigations**

The manufacturer of the tram indicated that incorrect installation and maintenance by Yarra Trams could be the cause of open circuit failures. Siemens advised that they inspected the EBUs on two trams (Tram 5007 on 15 July 2011 and Tram 3506 on 13 September 2011) and found that the cause of open circuits was the incorrect installation of the earth brush holder.

### **2.6.7 Manufacturer of the EBU**

The EBU used on the Combino motor bogies is manufactured by a Belgian company. The investigation wrote to the principal of the company to obtain information concerning world-wide experience with the unit but did not receive a response.



### **3. ANALYSIS**

#### **3.1 The incident**

Tram 3515 derailed at a set of points within the Melbourne University terminus following an operational decision by the traffic officer to override the automatic Points Controller and move the tram into a shunt already occupied by another tram. This shunt manoeuvre would have proceeded without incident except that the points providing the turnout to the shunt moved as Tram 3515 passed over them, when the automatic Points Controller restored the points from № 1 Shunt to the straight seeking to place the tram into № 2 Shunt which had become vacant.

The automatic Points Controller had functioned as designed. The points would not have moved had the leading bogie of the tram been detected on the Track Circuit, which it was not. As a result, the Mass Detector for the points was not activated (and therefore the points not held in position), allowing the points to move under the tram.

The reason the tram was not initially detected was because two of the EBUs on the same side of the leading bogie were unserviceable. The automatic Points Controller then called for the points to be changed prior to the trailing bogie, which had sufficient EBU function for tram detection, being detected on the Track Circuit. As a result, the Mass Detector for the points was not activated (and therefore the points not held in position), allowing the points to move under the tram.

#### **3.2 Shunt operations**

The manual overriding of the automatic Points Controller was a practice adopted by the network operator sometime prior to May 2009. Overriding any system has inherent risks; however, the network operator was not able to present evidence that a risk assessment examining the procedural changes was undertaken. Again, had such a risk assessment been done, particularly with consideration of the infrastructure design, it is likely that the incident scenario would have been examined and mitigations put in place to reduce the likelihood of derailment.

#### **3.3 Infrastructure modifications**

A shortened Track Circuit (carried out in 2005 to allow two trams to occupy the platform simultaneously), when combined with the operator's rolling stock policy of only requiring one operational circuit loop per D Class tram, left the operation susceptible to events such as this incident. In this case, the only serviceable operational circuit loop happened to be on the rear bogie and the № 1 points were able to move before the tram was detected by the Track Circuit.

Therefore, it would appear that the operations and rolling stock maintenance sections of Yarra Trams were either not appraised of, or did not understand, the potential effect of the infrastructure changes on tram movements. Had an adequate risk assessment been conducted then it is likely that mitigation would have been put in place to reduce the chance of derailment.

### **3.4 Operator internal communications**

This incident highlights issues arising from lack of internal company communications and coordination. There appears to have been no robust method whereby operational and infrastructure areas of the company were fully informed of the actions of the other and joint risk assessment conducted prior to changes in either area. Had such a process existed, the altering of an automated system for apparently valid operational reasons was unlikely to have lead to this derailment.

### **3.5 Earth brush unit**

#### **3.5.1 EBU reliability**

The correct functioning of an EBU is necessary for a tram to be detected by Track Circuits. On Tram 3515 three of the four wheels on the same side of the tram had open circuits because the EBUs were unserviceable.

The problems with EBUs have been on-going since the Combino trams were introduced into service in 2003. Despite modifications to the unit by the EBU manufacturer there appears to remain unresolved issues with the unit's functionality and reliability. Yarra Trams has a responsibility to provide safe tram operations and the malfunction of EBUs over the past eight years is a safety matter that needs to be resolved at the earliest with Siemens and the EBU manufacturer.

In the absence of information from the EBU manufacturer on other tram applications and international experience with EBU failures, it is difficult to tease out potential issues with the unit design, its compatibility with the Combino tram or installation and maintenance practices; all of which may in some way contribute to its lack of reliability. However, failures in this instance involved fracture of the earth shunt braids, suggesting rotary movement of the contact washer, possibly exacerbated by removal of the longitudinal locating pins in Version 3 of the unit.

#### **3.5.2 Maintenance inspection**

The investigation noted that none of the periodic inspections (at 60, 15 and 5 weeks) included EBU resistance measurement to potentially detect internal defects within the unit, not otherwise evident by visual inspection.

It is not possible to conclude when each of the EBUs on Tram 3515 became unserviceable; however, had resistance tests been undertaken as part of the periodic inspection regime, the defective EBUs may have been identified prior to the incident.

## **4. CONCLUSIONS**

### **4.1 Findings**

1. The automated control systems that managed shunt movements at Melbourne University terminus was designed to allocate only one tram to each shunt.
2. The network operator made an operational decision to allow the manual override of the automatic Points Controller to enable two trams to be stabled in № 1 Shunt
3. Track Circuit 1 was shortened, reducing the opportunity for timely tram detection.
4. Three of the four earth brush units on the same side of Tram 3515 were unserviceable.
5. Earth brush units on Combino trams have not operated successfully since the tram was introduced into service in 2003.

### **4.2 Contributing factors**

1. The operator did not undertake a risk assessment prior to introducing a procedure to stable two trams in № 1 Shunt at Melbourne University terminus.
2. The automatic Points Controller was overridden by the manual operation of the points servicing the № 1 Shunt.
3. Defective earth brush units on the leading bogie of Tram 3515 prevented the timely detection of the tram by Track Circuits.
4. Inadequate action has been taken to resolve long term reliability issues with earth brush units fitted to Combino trams and to manage potential affects on network safety.



## **5. SAFETY ACTIONS**

### **5.1 Safety Actions taken since the event**

#### **5.1.1 Block trams**

Immediately following the incident, Yarra Trams stopped stabling a 'block tram' at the Melbourne University terminus № 1 Shunt and issued a safety alert advising drivers that when approaching automatic points, the tram must remain at the One Stud marker until the tram ahead has fully cleared the points intersection.

On 8 December 2011, Yarra Trams resumed the practice of stabling a block tram at № 1 Shunt but disconnected № 1 Shunt and № 1 points from the automatic Points Controller. In this condition, № 1 points must be manually switched to enable a 'double shunt' into № 1 Shunt but the points cannot revert unless they are manually switched back to the straight.

Yarra Trams is developing a software upgrade, which when installed, will automatically cancel all commands stored in the automatic Points Controller when the system is manually overridden.

Additionally, Yarra Trams is considering engaging a third party engineer to assess the issues.

#### **5.1.2 Wheel resistance measurements**

Following the incident, track circuit loops at the entrances to Malvern and Southbank depots have been connected to data loggers to record tram wheel earth brush unit resistance measurements each time a tram enters or departs. The results are reviewed weekly and follow up action is taken as necessary. Yarra Trams have now reduced the acceptable upper limit of wheel resistance measurement from 300 milliohms to 150 milliohms.

#### **5.1.3 Earth brush unit modification**

Yarra Trams and Siemens are conducting a trial on one D class Combino tram with earth brush units from another manufacturer. Until trials demonstrate the reliability of the unit and the fleet is upgraded, Yarra Trams is considering undertaking earth brush unit resistance measurements during the 15-weekly servicing of the units and mandatory replacement of earth brush units and wheel bearings every eight years.

## **5.2 Recommended Safety Actions**

### **Issue 1**

The decision taken by the operator related to platform infrastructure changes and the stabling of two trams in № 1 Shunt appear not to have been adequately coordinated between the operational and infrastructure departments of the organisation.

### **RSA 2012013**

That Yarra Trams reviews its internal processes with the aim of ensuring that any changes to either operational procedures or infrastructure are the subject of an adequate risk assessment.